Cultivos Tropicales vol. 21, no. 4, October-December, 57-62, 2000

RICE GROWTH RESPONSE TO DIFFERENT PROPORTIONS OF APPLIED NITROGEN FERTILIZER

R. Castro✉ and Abu Bakar Siddique Sarker

ABSTRACT. The present work was carried out at the Tsukuba International Center (TBIC), Ibaraki, Japan, from May to September, 1999, in order to find out plant response to different proportions of nitrogen split application and its components involved in yield. Yumehitachi, a rice variety of Japonica type, was used with three different relations between the basal and top dressing application of a level of 90 kg $N.ha^{-1}$. High grain yields were obtained using the treatments of 45 (basal) and 45 (top dressing) kg $N.ha^{-1}$. In this treatment, plants were able to produce a high effective tiller and percentages of ripened grains. The highest root number of rice plants was recorded in the first 10 cm and were negatively affected by nitrogen applications but positively by tiller number.

RESUMEN. El presente trabajo se desarrolló en el Centro Internacional de Tsukuba (TBIC), Ibaraki, Japón, de mayo a septiembre de 1999, con el objetivo de conocer la respuesta de las plantas a diferentes proporciones de nitrógeno. Se utilizó la variedad Yumehitachi de tipo Japónica; se usaron tres relaciones diferentes entre el primero y el segundo fraccionamiento de una dosis de 90 kg $N.ha^{-1}$. Se obtuvieron rendimientos altos en el tratamiento de 45 (basal) y 45 (superficial) kg $N.ha^{-1}$ respectivamente. En este tratamiento la planta pudo producir gran cantidad de hijos efectivos y porcentaje de granos maduros. La mayor cantidad de raíces de la planta de arroz se encontró en los primeros 10 cm y estas son negativamente afectadas por aplicaciones de nitrógeno y positivamente por el número de hijos de las plantas.

Key words: rice, nitrogen, growth, root, varieties, crop yield, application rates

Palabras clave: arroz, nitrógeno, crecimiento, raíz, variedades, rendimiento de cultivos, dosis de aplicación

INTRODUCTION

Rice is the most important single food crop in the world today. Its importance will continue to increase in the decade ahead because population growth in rice-consuming areas is more rapid than in nonrice-consuming ones (1). Nitrogen is one of the most important elements for the rice plant. Thus, a large amount is necessary to achieve high grain yields (2, 3). In recent years, the remarkable increase in rice yields is attributed to high-yielding varieties that are highly responsive to N, increased and improved water supply, increased fertilizer application, as well as to a better management practice. Early researches have focused on the effect of N and yield-determining processes. Likewise, evaluations of varietal differences in response to N were conducted mainly on comparative analysis of traditional and improved varieties in terms of yield, carbohydrate metabolism and ripening grain (4, 5, 6). Other studies were directed to the morphological characterization of those varieties under varying N levels (4). The application of nitrogen enhances both photosynthetic activity and total dry matter production above ground. Moreover, it plays an important role in the formation and death of tillers, as well as the differentiation and degeneration of spikelets (7, 8).

This work is focused on plant response to different rates of applied nitrogen, yield and its components.

MATERIALS AND METHODS

Site and type of experiment. An experiment was conducted at the experimental field of Tsukuba International Center (TBIC) in Tsukuba, Japan, from May to September, 1999, during a Rice Research Techniques Course.

The soil was classified as an alluvial clay loam and applied on a Hapludand. Soil chemical properties at the land preparation stage are shown below.

- pH 6.2 (glass-electrode)
- Organic carbon 2.15 % (Kosaka, Honda & Iseki)
- Organic matter 3.70 % (Ditto)
- Total nitrogen 0.17 % (Kjeldhal)
- CEC 13.5 $mol.kg^{-1}$ (Shollenberger)
- Available phosphorus 2 mg $P_2O_5.kg^{-1}$ (Truog)
- Phosphate adsorption 2600 $mg.100g^{-1}$ (2.5 % $(NH_4)_2HPO_4$)
- Available zinc 0.38$mg.kg^{-1}$ (0.1N-HCl).

Treatments and design. The treatments made with three different nitrogen applications, at various ratios of basal to top dressing, were designed as shown in Table I.

R. Castro Jr., Researcher from the Plant Nutrition and Biofertilization Department, Rice Research Station (INCA), Los Palacios, Pinar del Río, Cuba. Abu Bakar Siddique Sarker, Research Officer from the Agronomy Division, Bangladesh Rice Research Institute (BRRI), Gazipur- 1701, Bangladesh.

✉ Corresponding author: e-mail: palacios@inca.edu.cu

Table I. Treatments used

Treatments	Nitrogen ($kg.ha^{-1}$) Basal	Top dressing
N1	80	10
N2	60	30
N3	45	45

All plots (15 $m^2.plot^{-1}$) were arranged in a randomized complete block design with three replications.

Cultural management. Seedlings of the tested rice variety Yumehitachi were transplanted as three-seedlings.$hill^{-1}$ at a spacing of 30x15cm, on May 7, 1999.

Application of other fertilizers (100 and 80 $kg.ha^{-1}$ of P_2O_5 and K_2O, respectively) was carried out one day before transplanting. Irrigation water was maintained about 3 to 5 cm deep until heading time and herbicide was also applied once to control weeds. The standard rice cultivation method of Japan was used.

Observation of agronomic characteristics. Six hills per plot were sampled to measure leaf area and dry matter. Leaf area was measured using the automatic leaf area meter (Hayashi Denko Co., Ltd.). After measuring leaf area, the dry matter of all plant material was recorded. To determine dry matter, samples were dried at 80^o C for 48 hours. The nitrogen content of each plant was determined at the panicle initiation and harvesting times.

Roots were sampled at the active tillering and heading stages. The cylinder monolith method was used for root weight density determination. Data were then statistically processed for its interpretation.

The results of this observation enabled to determine crop growth rate (CGR) and to correlate among themselves.

RESULTS AND DISCUSSION

Yield. Table II shows the influence of treatments on grain yield, its components and sink size. The highest yield was observed at N3 level, which was significantly higher than in N1.

Panicles per square meter, 1000-grain weight and percentage of ripened grains showed a similar behavior as yield, although the number of spikelets per panicle did not show any significant difference.

The relationship between yield and its components is shown in Table III. The percentages of ripened grains showed the highest correlation value with yield, followed by panicles per square meter. The percentage of ripened grains was higher in treatments N2 and N3, because plants had more nutrients in the late growing stage and it was directly related with yield (Figure 1). This also causes the plants to be active in most of its leaf area (Figure 2). Therefore, plants can produce high quantities of starch to fill grains.

Table III. Correlation matrixes for yield and its components

	Yield	Grain. $panicle^{-1}$	1000-grain weight	Grain. $panicle^{-1}$
Percentage of ripened grains	0.908***	0.041	0.733*	0.678
Grain.$panicle^{-1}$	0.313*	0.384	0.693	
1000-grain weight	0.693*	0.667		
Panicle.m^{-2}	0.838**			

*, **, *** Significant at 5, 1 and 0.1 level, respectively

The panicles per square meter were higher in treatments N2 and N3, which was caused by top dressing fertilization. This had an influence on effective tillers. In Figure 3, it can be observed that treatment N1 achieved less percentage of effective tillers than treatments N2 and N3. This percentage can be affected by the emergence of secondary tillers, which is attributed to high temperature and nitrogen applications that keep a great amount of available nitrogen in the soil. The secondary tillers yielded panicles that were mature at harvesting stage.

Table II. Yield and its components

Treatment	Panicle.m^{-2}	1000-grain weight (g)	Spikelet.$panicle^{-1}$	Percentage of ripened grain	Yield ($t.ha^{-1}$)	Sink size ($t.ha^{-1}$)
N1	281.9 b*	26.1 b*	85.4 ns	80.7 b*	5.0 c*	6.3 b*
N2	315.2 ab	26.4 ab	88.0	88.7 a	6.5 b	7.3 a
N3	328.4 a	26.7 a	88.1	89.4 a	6.9 a	7.7 a
SE x	0.6884	0.0319	1.0514	0.1326	0.0543	0.0527

* In each column, common letters indicate nonsignificant differences by Duncan's Multiple Range Test at p=0.05

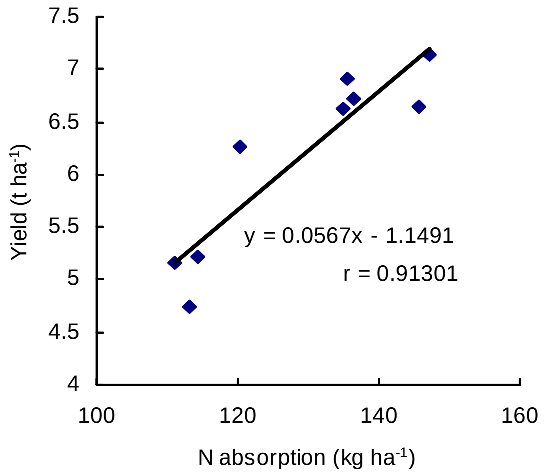

Figure 1. Relationship between N absorption and yield at harvesting time

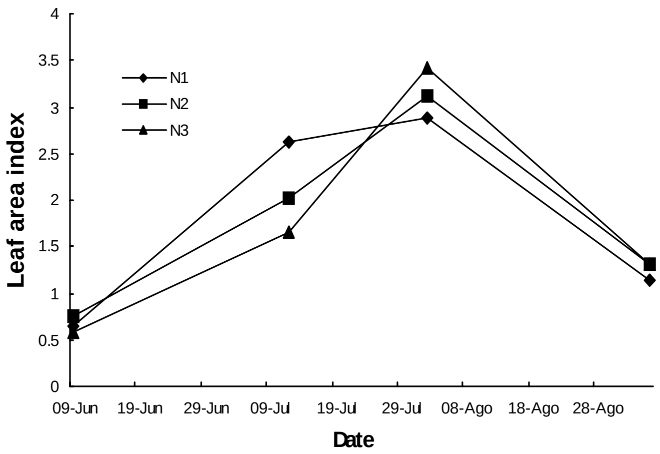

Figure 2. Leaf area index with different nitrogen rate applications

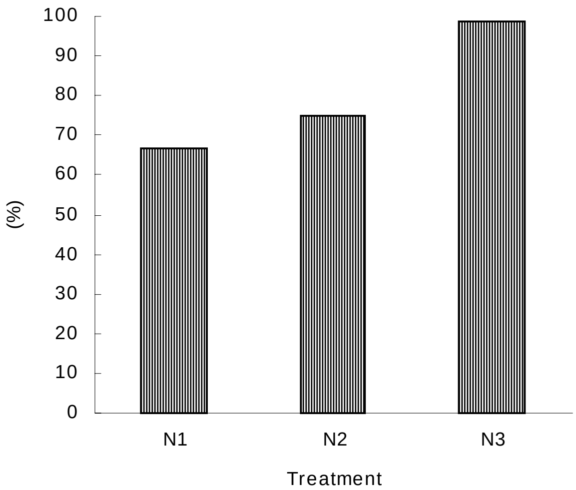

Figure 3. Effective tillering percentage

Growth at the active tillering stage (9 June). In Figure 4, plant growth is represented in terms of dry matter. As it can be noted, no significant differences were detected among treatments until the active tillering stage. This behavior can be explained, taking into account that the different amounts of basal nitrogen applied in all treatments guarantee the nutritional requirements of plants until this phase.

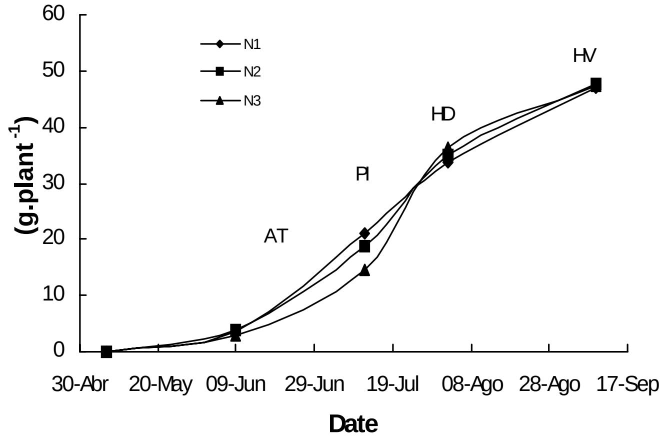

Figure 4. Dry weight of growth

A similar explanation can be applied to the results observed in Figure 5, where there was not a significant correlation of N application and dry weight until this stage. Therefore, in Figure 2, a clear difference cannot be observed in the leaf area index; this fact is in agreement with the results obtained (9) under similar conditions. It can also be observed in Table IV that there was not a clear trend of the different treatments in CGR at the active tillering stage.

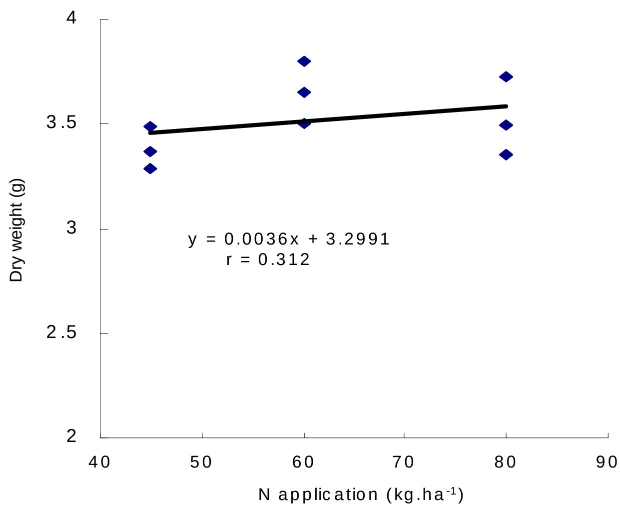

Figure 5. Relationship between N application and dry weight of varieties at active tillering stage

Table IV. Crop growth rate (CGR) at different stages

Treatment	Tran-AT	At - PI
N1	2.34	11.72
N2	2.61	10.02
N3	1.90	7.95

Tran= Transplanting; AT= Active tillering stage;PI= Panicle initiation stage

Figure 6(a-b) shows root growth. Root amount decreases in the first 10 cm with the amount of the basal nitrogen level. Some authors (10) obtained similar results. In Figure 7, tiller number was related to dry matter of roots. Although the number of tillers determined the amount of roots, a clear relationship was not observed; a probable cause could be that nitrogen became a limiting factor due to the high basal nitrogen applications.

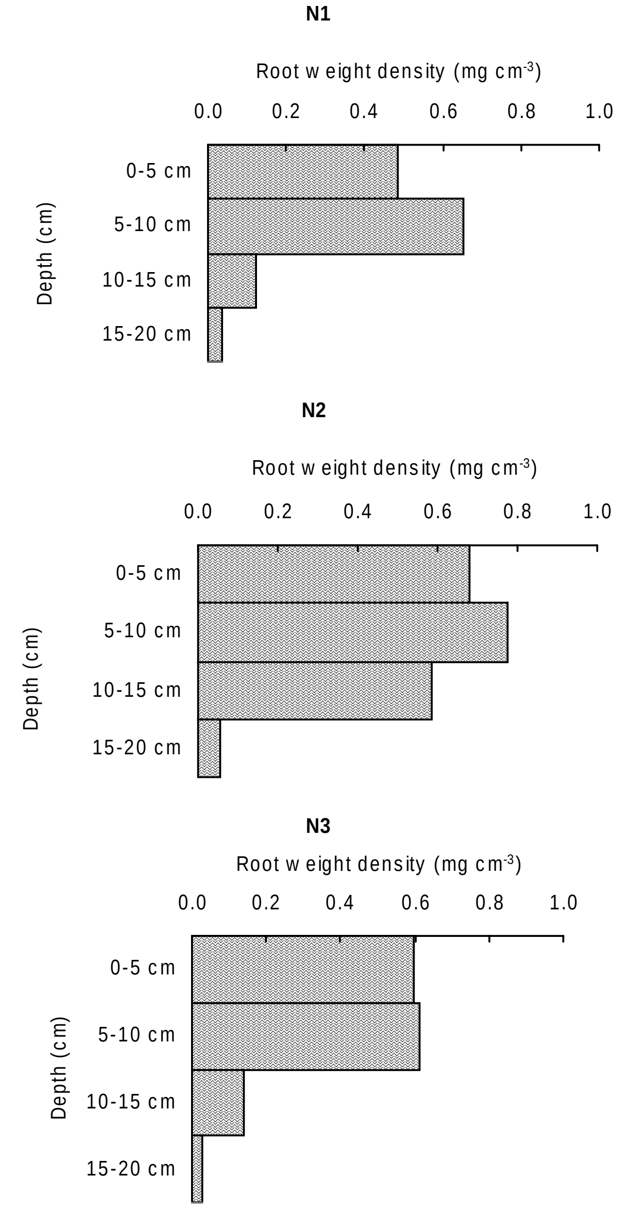

Figure 6a. Root weight density at active tillering stage

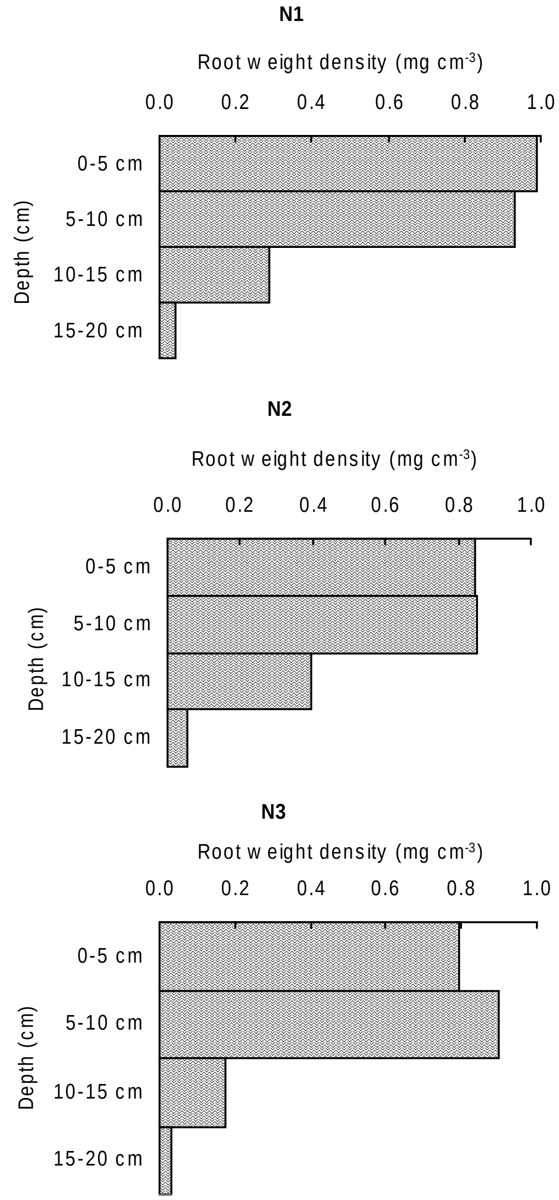

Figure 6b. Root weight density at heading stage

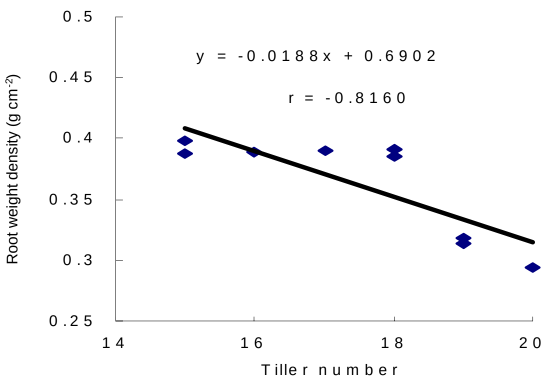

Figure 7. Relationship between tiller number and root weight density at active tillering stage

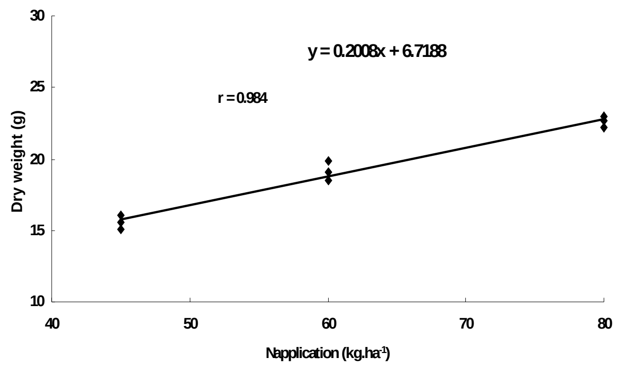

Figure 8. Relationship between N application and dry weight at panicle initiation stage

Growth at the panicle initiation stage (12 July). A difference in the dry matter production for all treatments was observed in Figure 4. Treatment N1 gave the highest dry matter production because a greater amount of basal nitrogen level was applied. A similar response can be seen (Table IV) in CGR tendency.

In Figure 8, a clear relationship was observed between nitrogen application and dry weight of the plant. As shown in Figure 9, there was a high correlation between absorbed nitrogen and dry matter production.

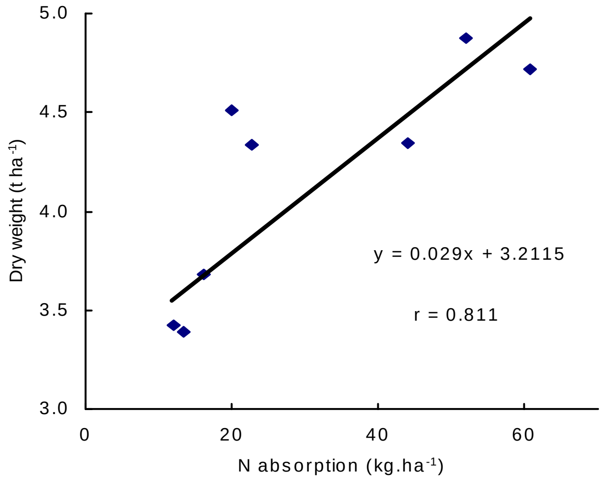

Figure 9. Relationship between N absorption and dry weight at panicle initiation stage

Figure 2 shows the trend of leaf area index. Leaf area increased with plant nitrogen content. A similar response was observed in the previous study.

In Figure 10, the relationship between N absorption and yield is shown. Although plants of the treatment N1 absorbed more N until panicle initiation stage, they did not obtain high yields. Nitrogen absorption at the early stages of the plant does not necessarily have a definitive influence on yields if treatments are used with different proportions of fraction from a final dose.

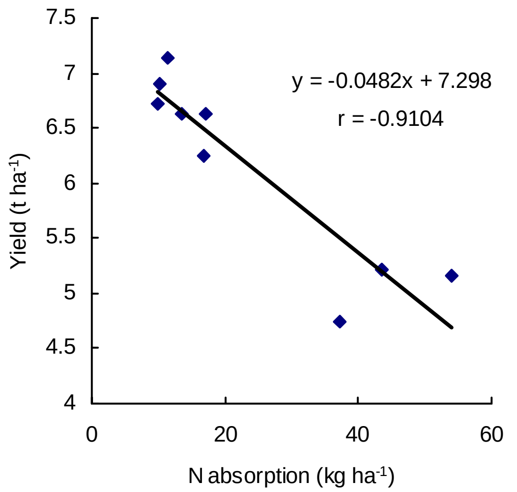

Figure 10. Relationship between N absorption and yield at panicle initiation stage

Growth until heading stage (2 August). It can be seen from Figure 4 that in this stage, N3 has the highest dry matter production, followed by N2. This can be related to top dressing application levels, which were 10, 30 and 45 kg N.ha^{-1} for treatments N1, N2 and N3, respectively. In treatment N1, plants tend to reduce nitrogen amount in the top dressing and therefore they cannot keep dry matter increase. This resulted to a decrease in photosynthetic active leaf area (Figure 2). Regarding N3, an inverse behavior occurred compared to that of treatment N1. After high top dressing levels, the plant accelerated its growth and its leaf area increased.

In Figure11, a clear relationship between tiller number and root dry matter is shown. It is necessary to point out that the different applications of nitrogen can positively influence this relationship.

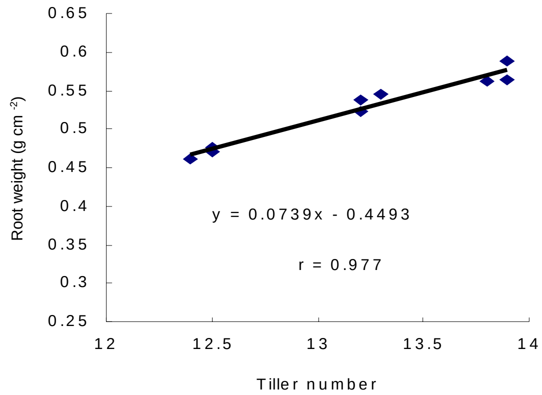

Figure 11. Relationship between tiller number and root weight density and at heading stage

Growth until harvesting stage (9 September). Figure 3 shows that there was no differences in dry matter among those treatments, because total nitrogen level is equal in all of them. In general, the nitrogen proportions used have no great effect on total dry matter. A similar response is shown for the leaf area index (Figure 2), which decreases and does not cause a clear difference among treatments.

The percentage of effective tillers is shown in Figure 3. In this case, treatment N3 (45-45) has a higher quantity of effective tillers. However, in treatment N1 (80-10), the amount of effective tillers was lower because top dressing application was not enough for the plant to keep high amounts of tillers; this caused a high death percentage before heading.

The relationship between dry matter and nitrogen absorption is shown in Figure 12. It can be observed from this figure that not any relationship exists among both variables used. This response is influenced by the equal dry matter production of different treatments at this moment. However, the absorbed nitrogen did show a high correlation with yield (Figure 1); this product in which variants specifically used top dressing application had a great effect on yield, to give nutrients at the time of panicle and spikelet formation as well as flowering and ripened grains. A similar response was observed (2).

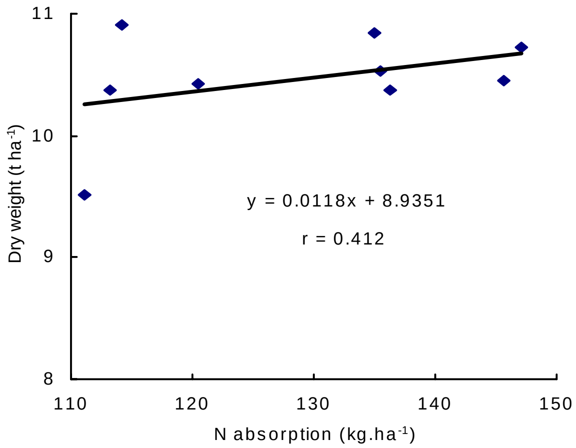

Figure 12. Relationship between dry weight and N absorption at harvesting time

CONCLUSIONS

1. Yield has a high correlation with the absorbed nitrogen, which was also influenced by nitrogen top dressing.
2. When different rates of basal nitrogen and top dressing were used, the percentage of ripened grains and panicles per square meter were the main components that influenced yield.
3. When different proportions of a total level of nitrogen were used, dry matter production did not significantly differ among the different treatments used.
4. Leaf area was related to basal nitrogen application at the panicle initiation stage and to nitrogen top dressing at the heading stage.
5. The percentage of effective tillers was related to high nitrogen top dressing application.
6. The amount of roots is positively influenced by the number of tillers but negatively by the amount of applied nitrogen.

ACKNOWLEDGEMENT

The author wishes to express his deepest gratitude to the government of Japan, the government of Cuba and to the Japan International Cooperation Agency (JICA) for the financial support of the training. The support and assistance provided by the staff members of the Tsukuba International Center are highly appreciated. I would like to give my special thanks to all the members of the Rice Section for their kind cooperation and assistance, and special thanks are due to Mr. N. Kojima, Dr. J. Sakagami and Mr. T. Seiji, for their continuous effort in the successful completion of this study. I would also like to thank my colleagues in the course, especially Khin Mar Kyu.

REFERENCES

1. Than, H. Study of the effect of sulfate application on the growth and yield of japonica rice (*Oryza sativa L.*).Tsukuba International Center. Japan International Cooperation Agency (JICA). Report on experiments in Rice Research Techniques Course. Japan 2: 33-48, 1998.
2. Wada, O. The effects of nitrogenous nutrition on yield determining process of rice plant. *Bull Natl. Agric. Sci*. 1969, vol. 16, p. 27-157.
3. Rao, K. S. and Moorthy, B. T. S. Response of rice (*Oryza sativa*) varieties of different durations to level of nitrogen in coastal alluvial soils of Orissa in wet season. *Indian Journal of Agricultural Sciences*, 1995, vol. 65, no. 6, p. 394-398.
4. Yoshida, S. Fundamentals of rice. *Crop Science*, 1981, p. 235-237.
5. Reddy, B. B. and Reddy, D. R. Performance of rice varieties under late planted conditions in wet season and their response to nitrogen. Andhara Pradesh Agricultural University Andhara Pradesh. Regional Agricultural Research Station. India. *Journal of Research APAU*, 1996, vol. 29, p. 3-4.
6. Reddy, B. B., Rao, L. J. and Reddy, D. R.. Response of rice varieties to nitrogen application during dry season. Andhara Pradesh Agricultural University. Andhara Pradesh. Regional Agricultural Research Station. India. *Journal of Research APAU*, 1996, vol. 24, p. 1-2.
7. Avellanoza-Prudente, J. Nitrogen uptake patterns of japonica and indica rice varieties applied with varying levels of nitrogen fertilizer. Tsukuba International Center. Japan International Cooperation Agency (JICA). Report on experiments in Rice Research Techniques Course. Japan. 1: 57-76, 1997.
8. Imtiaz, M. A. A. Effect of N nutrition on single leaf photosynthesis and yield of japonica rice. Tsukuba International Center. Japan International Cooperation Agency (JICA). Report on experiments in Rice Research Techniques Course. Japan. 1: 87-93, 1996.
9. Zefu, Li. Varietal differences in rice agronomic characters under different rates of nitrogen topdressing. Tsukuba International Center. Japan International Cooperation Agency (JICA). Report on experiments in Rice Research Techniques Course. Japan. 1: 1-8, 1997.
10. Tanaka, S., Yarnauchi, A. and Kono, Y. Root system morphology of four rice cultivars: Response of different component roots to nitrogen application. *Japanese Journal of Crop Science*, 1995, vol. 64, p. 148-155.

Received: April 12, 2000
Accepted: April 21, 2000